Journal of Advanced Research in Food Science and Nutrition
Volume 7, Issue 1 - 2024, Pg. No. 12-16
Peer Reviewed Journal

Review Article

An Overview of Advances in Food Packaging and Engineering

Ananya Pandey

Student, Department of Agricultural Sciences, IIMT University, Meerut, India.

INFO

E-mail Id:
ananyapandey19102003@gmail.com
Orcid Id:
https://orcid.org/0009-0002-9050-2954

How to cite this article:
Pandey A. An Overview of Advances in Food Packaging and Engineering. *J Adv Res Food Sci Nutr* 2024; 7(1): 12-16.

Date of Submission: 2024-04-30
Date of Acceptance: 2024-06-15

ABSTRACT

The field of food packaging and engineering has seen significant advancements driven by the need to extend shelf life, ensure food safety, and address environmental sustainability. This review provides an overview of recent developments in packaging materials, technologies, and engineering methods. Key innovations include biodegradable and edible packaging materials, such as polylactic acid (PLA) and protein-based films, which offer sustainable alternatives to traditional plastics. Active and intelligent packaging systems, incorporating oxygen scavengers and time-temperature indicators (TTIs), enhance product preservation and provide critical information on food quality. Engineering innovations like Modified Atmosphere Packaging (MAP) and High-Pressure Processing (HPP) extend the shelf life and safety of food products without compromising their sensory qualities. Nanotechnology, through the use of antimicrobial nanoparticles and improved barrier properties, further enhances packaging performance. Additionally, efforts towards sustainability are emphasized through recycling, reusability, lightweighting, and minimalist design. This review highlights how these advancements are reshaping the food packaging industry, contributing to better consumer experiences and environmental stewardship.

Keywords: Biodegradable Packaging, Modified Atmosphere Packaging (MAP), High-Pressure Processing (HPP), Nanotechnology in Packaging, Sustainable Food Packaging

Introduction

Food packaging plays a pivotal role in the modern food supply chain, serving as a critical interface between food products and consumers. Its primary functions include protecting food from physical, chemical, and biological hazards, preserving the quality and freshness of food, facilitating transportation and distribution, and providing essential information about the product. The design and engineering of food packaging require a multidisciplinary approach, integrating principles from materials science, food chemistry, microbiology, mechanical engineering, and environmental science.

In recent years, the food packaging industry has been under increasing pressure to address a variety of challenges. Consumer demands for convenience, transparency, and sustainability have driven the need for innovative packaging solutions. There is also a growing awareness of the environmental impact of traditional packaging materials, particularly plastics, which has led to a surge in research and development of eco-friendly alternatives. Furthermore, global supply chains and the rise of e-commerce have introduced new considerations for packaging durability and efficiency.[1]

Technological advancements are transforming the capabilities of food packaging, making it more interactive

Copyright (c) 2024: Author(s). Published by Advanced Research Publications

and responsive to the conditions of the food it encases. Active and intelligent packaging systems are now able to monitor and respond to changes in the environment, thereby enhancing the safety and shelf life of food products. Engineering innovations, such as Modified Atmosphere Packaging (MAP) and High-Pressure Processing (HPP), are pushing the boundaries of how we preserve and protect food.

This review article aims to explore these recent advancements in food packaging materials, technologies, and engineering methods. By examining biodegradable and edible packaging, active and intelligent systems, cutting-edge processing techniques, and sustainable practices, we can gain a comprehensive understanding of how the field is evolving to meet contemporary challenges and future needs.[2]

Advances in Packaging Materials

The development of new packaging materials is fundamental to improving food preservation, safety, and sustainability. Recent innovations in this area have focused on creating biodegradable, edible, and intelligent materials that meet the demands of both consumers and regulatory bodies. These advancements are designed to address environmental concerns, enhance the functionality of packaging, and provide better protection for food products.

Biodegradable and Edible Packaging

The environmental impact of traditional plastic packaging has led to increased interest in biodegradable and edible packaging materials. These alternatives are designed to reduce waste and improve sustainability without compromising food safety and quality.

- **Polylactic Acid (PLA):** Polylactic Acid (PLA) is a biodegradable polymer derived from renewable resources such as corn starch or sugarcane. It has gained significant traction as an alternative to petroleum-based plastics due to its compostable properties and reduced environmental impact. PLA is used in a variety of food packaging applications, including containers, films, and wrapping materials. Its ability to degrade into non-toxic compounds makes it an attractive option for reducing plastic waste in landfills.
- **Applications:** PLA is commonly used for packaging fresh produce, bakery products, and ready-to-eat meals. Its clarity and strength are comparable to conventional plastics, making it suitable for a wide range of food products.
- **Advantages:** PLA packaging is compostable under industrial conditions, reducing the environmental footprint. Additionally, its production from renewable resources aligns with sustainability goals.
- **Edible Films and Coatings**: Edible films and coatings are made from natural polymers such as proteins (e.g., casein, soy protein), polysaccharides (e.g., cellulose, starch), and lipids (e.g., waxes, oils). These materials can be applied directly to food surfaces, forming a protective barrier that helps to retain moisture, inhibit microbial growth, and reduce oxidation.
- **Applications:** Edible films are particularly useful for fruits, vegetables, meats, and dairy products. For instance, they can be used to coat apples to prevent dehydration and browning or to cover meats to reduce microbial contamination.
- **Advantages:** Edible films enhance the shelf life and quality of food without introducing inedible packaging waste. They can also carry functional ingredients such as antimicrobials, antioxidants, and flavors.

Active and Intelligent Packaging

Active and intelligent packaging systems are designed to interact with food products to enhance preservation and provide information on the condition of the product.

- **Oxygen Scavengers:** Oxygen scavengers are materials that absorb oxygen from the environment within the package, thereby preventing the oxidation of food products. These scavengers can be integrated into packaging films or included as sachets inside the package. By reducing oxygen levels, they help to preserve the color, flavor, and nutritional value of food.
- **Applications:** Oxygen scavengers are widely used for packaging high-fat foods, snack foods, dairy products, and meat products. They are particularly beneficial for extending the shelf life of products prone to oxidative spoilage.
- **Advantages:** These materials improve food safety and quality by inhibiting the growth of aerobic microorganisms and delaying rancidity.
- **Time-Temperature Indicators (TTIs):** Time-Temperature Indicators (TTIs) are devices or labels that visually indicate the history of temperature exposure of a food product. These indicators change color based on the cumulative time and temperature conditions the product has experienced, providing a clear signal of potential spoilage or safety risks.
- **Applications:** TTIs are used for monitoring perishable products such as seafood, dairy, and pharmaceuticals during transportation and storage. They are especially useful in cold chain logistics to ensure that products remain within safe temperature ranges.
- **Advantages:** TTIs help to ensure the integrity and safety of food products by providing real-time monitoring and easy-to-interpret signals of temperature abuse.[3-7]

Nanotechnology in Packaging

Antimicrobial Nanoparticles

Nanotechnology involves incorporating nanoparticles, such as silver or zinc oxide, into packaging materials to provide antimicrobial properties. These nanoparticles can inhibit the growth of bacteria, fungi, and other pathogens, thereby extending the shelf life and safety of food products.

- **Applications:** Antimicrobial packaging is used for perishable foods such as meat, poultry, fish, and dairy products. It is also employed in packaging for fresh fruits and vegetables.
- **Advantages:** The use of antimicrobial nanoparticles reduces the need for chemical preservatives, maintains food quality, and enhances food safety by preventing microbial contamination.

Improved Barrier Properties

Nanocomposites, which combine nanoparticles with polymer matrices, significantly enhance the barrier properties of packaging materials. These composites can effectively reduce the permeability of gases, moisture, and UV light, providing better protection for the food inside.

- **Applications:** Improved barrier materials are used for packaging sensitive products such as snacks, beverages, and high-fat foods. They are also utilized in packaging applications that require extended shelf life, such as vacuum-packed and modified atmosphere packaged foods.
- **Advantages:** Nanocomposites enhance the shelf life and quality of food products by providing superior protection against environmental factors. They also offer mechanical strength and durability, reducing the risk of package damage.

Engineering Innovations in Food Packaging

Advances in food packaging engineering are crucial for improving food safety, extending shelf life, and meeting consumer demands for convenience and sustainability. This section explores significant engineering innovations, including Modified Atmosphere Packaging (MAP), High-Pressure Processing (HPP), and the application of nanotechnology. These innovations enhance the functionality and efficiency of food packaging systems, offering new solutions to longstanding challenges in the food industry.

Modified Atmosphere Packaging (MAP)

Modified Atmosphere Packaging (MAP) is a technology that alters the atmosphere within a food package to slow down the growth of microorganisms and the oxidation of food, thereby extending shelf life. This is achieved by modifying the levels of gases such as oxygen, carbon dioxide, and nitrogen.

Principles of MAP

MAP works by replacing the atmospheric air inside the package with a specific gas mixture tailored to the type of food being packaged. Typically, oxygen levels are reduced to slow down aerobic microbial growth and oxidation, while carbon dioxide levels are increased to inhibit the growth of spoilage organisms and pathogens. Nitrogen, an inert gas, is often used as a filler to prevent package collapse.

- **Applications:** MAP is widely used for packaging fresh produce, meats, fish, baked goods, and ready-to-eat meals. For instance, fresh meats are often packaged in high-oxygen atmospheres to maintain their red color, while fruits and vegetables are packaged in low-oxygen atmospheres to reduce respiration and delay ripening.
- **Benefits:** MAP significantly extends the shelf life of food products without the need for chemical preservatives. It also helps to maintain the sensory qualities of food, such as texture, flavor, and appearance.

High-Pressure Processing (HPP)

High-Pressure Processing (HPP) is a non-thermal food preservation method that uses extremely high pressure to inactivate pathogens and spoilage microorganisms. Unlike traditional thermal methods, HPP preserves the sensory and nutritional qualities of food.

Mechanism of HPP

HPP involves subjecting food products to pressures between 100 and 600 megapascals (MPa) in a water-based medium. This high pressure disrupts the cellular functions of microorganisms, leading to their inactivation. Since the process does not involve high temperatures, the food's original flavor, color, and nutritional value are largely retained.

- **Applications:** HPP is used for a variety of products, including juices, smoothies, guacamole, deli meats, seafood, and ready-to-eat meals. It is particularly effective for products that are sensitive to heat and require a fresh-like quality.
- **Benefits:** HPP enhances food safety by effectively inactivating pathogens such as Listeria, Salmonella, and E. coli. It also extends the shelf life of perishable foods while maintaining their quality attributes.[8-10]

Nanotechnology in Food Packaging Engineering

Nanotechnology involves the use of materials and devices on an atomic, molecular, and supramolecular scale, typically less than 100 nanometers. In food packaging, nanotechnology is used to improve the mechanical, barrier, and antimicrobial properties of packaging materials.

Antimicrobial Nanoparticles

Embedding nanoparticles with antimicrobial properties, such as silver, zinc oxide, or titanium dioxide, into packaging materials can significantly enhance food safety. These nanoparticles can inhibit the growth of bacteria, fungi, and other pathogens on the surface of the packaging, thereby extending the shelf life of the food inside.

- **Applications:** Antimicrobial nanoparticle packaging is used for a variety of perishable foods, including fresh produce, meats, dairy products, and bakery items.
- **Benefits:** This technology reduces the need for additional chemical preservatives, ensuring that food products remain safe and fresh for longer periods. It also helps to mitigate the risk of foodborne illnesses.

Improved Barrier Properties

Nanocomposites, which incorporate nanoparticles into polymer matrices, enhance the barrier properties of packaging materials. These nanocomposites can effectively reduce the permeability of gases, moisture, and UV light, providing superior protection for food products.

- **Applications:** Packaging for snacks, beverages, dairy products, and other items that require extended shelf life and protection from environmental factors often uses nanocomposites.
- **Benefits:** Improved barrier properties help maintain the freshness, quality, and safety of food products. They also contribute to reducing food waste by extending the shelf life of packaged foods.

Sustainability in Food Packaging

As environmental concerns continue to rise, sustainability in food packaging has become a key focus for the food industry. Innovations aimed at reducing the environmental footprint of packaging materials, improving recycling processes, and promoting the reuse of packaging are critical to addressing these concerns. This section delves into various strategies and technologies that are driving sustainability in food packaging.

Recycling and Reusability

Closed-Loop Systems: Closed-loop recycling involves the collection and recycling of used packaging materials back into the production cycle to create new packaging. This system minimizes waste and conserves resources by keeping materials in use for as long as possible.

- **Applications:** PET bottles are a prime example of closed-loop recycling, where used bottles are collected, cleaned, and reprocessed into new bottles or other packaging products.
- **Advantages:** Closed-loop systems reduce the demand for virgin materials, lower greenhouse gas emissions, and decrease the amount of waste sent to landfills. They also support the circular economy by promoting resource efficiency and sustainability.
- **Reusable Packaging:** Reusable packaging solutions are designed to be used multiple times before being discarded or recycled. This approach reduces the need for single-use packaging and helps to minimize waste
- **Applications:** Examples include glass jars for dairy products, durable plastic containers for beverages, and metal tins for snacks. These containers can be returned, cleaned, and refilled multiple times.
- **Advantages:** Reusable packaging reduces waste, conserves resources, and often results in cost savings over the long term. It also aligns with consumer preferences for sustainable and eco-friendly packaging options.

Reduction of Packaging Waste

- **Lightweighting:** Lightweighting involves reducing the weight of packaging materials without compromising their strength and functionality. This can be achieved through material optimization, innovative design, and advancements in manufacturing technologies.
- **Applications:** Lightweighting is applied across various packaging formats, including bottles, cans, cartons, and flexible packaging. For instance, beverage companies have successfully reduced the weight of PET bottles by using less plastic while maintaining durability.
- **Advantages:** Lightweighting reduces material usage, lowers transportation costs, and decreases carbon emissions. It also helps companies meet regulatory requirements and consumer demands for more sustainable packaging.
- **Minimalist Packaging Designs:** Minimalist packaging designs focus on using the least amount of material necessary to protect and preserve the product. This approach often involves innovative folding techniques, efficient use of space, and the elimination of unnecessary components.
- **Applications:** Minimalist designs are common in product categories such as electronics, personal care items, and food products. Examples include concentrated product formulations that require smaller packaging and innovative folding designs for boxes and cartons.
- **Advantages:** Minimalist packaging reduces waste, lowers production and shipping costs, and appeals to environmentally conscious consumers. It also enhances the overall aesthetic and functionality of the packaging.[11-15]

Conclusion

Advancements in the packaging and engineering of foods and food products are essential for meeting the demands of modern consumers and addressing environmental concerns. Innovations in biodegradable materials, active and intelligent packaging, and advanced processing methods like MAP and HPP are enhancing food safety, extending shelf life, and improving sustainability. As technology continues to evolve, the integration of new materials and methods will play a critical role in the future of food packaging and engineering.

References

1. Aleksanyan KV. Polysaccharides for biodegradable packaging materials: Past, present, and future (Brief Review). Polymers. 2023 Jan 15;15(2):451.
2. Chen Q, Auras R, Uysal-Unalan I. Role of stereocomplex in advancing mass transport and thermomechanical properties of polylactide. Green Chemistry. 2022;24(9):3416-32.
3. Tharanathan RN. Biodegradable films and composite coatings: past, present and future. Trends in food science & technology. 2003 Mar 1;14(3):71-8.
4. Brody AL, Bugusu B, Han JH, Sand CK, McHugh TH. Innovative food packaging solutions. Journal of food science. 2008 Oct 1;73(8):107-16.
5. Alam MA, Khatoon R, Huda S, Sharma PK. Review on Advanced Food Packaging Materials Based on Functional Biopolymer Matrix. InBiomaterials in Food Packaging 2022 Sep 22 (pp. 181-218). Jenny Stanford Publishing.
6. Suppakul P, Miltz J, Sonneveld K, Bigger SW. Active packaging technologies with an emphasis on antimicrobial packaging and its applications. Journal of food science. 2003 Mar;68(2):408-20.
7. Pereira de Abreu DA, Cruz JM, Paseiro Losada P. Active and intelligent packaging for the food industry. Food Reviews International. 2012 Apr 1;28(2):146-87.
8. Ahvenainen R, editor. Novel food packaging techniques. Elsevier; 2003 Jun 10.
9. Baldwin EA, Nisperos-Carriedo MO, Baker RA. Use of edible coatings to preserve quality of lightly (and slightly) processed products. Critical Reviews in Food Science & Nutrition. 1995 Nov 1;35(6):509-24.
10. Krasaekoopt W, Bhandari B, Deeth H. Evaluation of encapsulation techniques of probiotics for yoghurt. International dairy journal. 2003 Jan 1;13(1):3-13.
11. Pawar JR, Phatak RS, Qureshi NM, Singh AE, Shinde MD, Amalnerkar DP, Doh J. Contemporary Trends in Active and Intelligent Polymer Nanocomposite based Food Packaging Systems for Food Safety and Sustainability in the Modern Aeon. Current Materials Science: Formerly: Recent Patents on Materials Science. 2024 Dec 1;17(4):358-85.
12. Robertson GL. Food packaging: principles and practice. CRC press; 2005 Sep 22.
13. Sumner SS, Peters DL. Microbiology of vegetables. InProcessing vegetables 2023 Jan 13 (pp. 87-114). Routledge.
14. Evrendilek GA. Principles of high pressure processing and its equipment. InNon-thermal Food Processing Operations 2023 Jan 1 (pp. 301-318). Woodhead Publishing.
15. Lagaron JM, Lopez-Rubio A. Nanotechnology for bioplastics: opportunities, challenges and strategies. Trends in food science & technology. 2011 Nov 1;22(11):611-7.